The Application of Microhole Technology to the Development of Coalbed Methane Resources at Remote Locations

James N. Albright[1], James G. Clough[2], and Donald S. Dreesen[1]
[1]Los Alamos National Laboratory, Los Alamos N.M., U.S.A.
Division of Geological & Geophysical Surveys, Department of Natural Resources, State of Alaska, Fairbanks, U.S.A.

Abstract.

The U. S. Department of Energy (DOE) through its Natural Gas and Oil Recovery Partnership Program with American industry, has undertaken an integrated program of development to show that the cost of obtaining subsurface information can be drastically reduced through microhole technologies specifically developed to obtain that information. Collectively termed "Microhole Drilling and Instrumentation Technology," the program objectives include: (1) drilling shallow microholes using currently available coiled tubing technology, (2) evaluating the feasibility of drilling deep microholes, (3) miniaturization and testing of bottomhole drilling assemblies, (4) miniaturization of geophysical logging tools, and (5) incorporating emerging miniature sensor technologies in borehole seismic instrumentation packages. The development of microhole technologies is underway at the DOE's Los Alamos National Laboratory. Microhole technology development is based on the premise that because of the historic advances in electronics and sensors, conventional-diameter wells are no longer necessary for obtaining subsurface information. Thus, the combination of deep microholes having diameters at their terminal depth ranging from 1-1/4 to 2-3/8 inches and logging tools have a 7/8-inch-diameter will comprise a very low cost alternative to currently available technology for exploration and reservoir characterization.

In collaboration with the Alaskan Department of Natural Resources, Los Alamos has examined requirements for applying microhole technology to the development of coalbed methane (CBM) resources in remote, environmentally sensitive areas. For microhole technology to be successfully used for CBM exploration, it appears that it is only necessary that existing commercial hardware and tools for coring, testing, and production be miniaturized. With regard to the use of microholes for production, significant issues remain as to whether de-watering, stimulation, and well maintenance can be successfully conducted with microholes.

Note. Even though our study focuses on remote Alaska and the potential impact that microhole technology could have on the development of CBM resources there, much of our analysis applies to comparable regions of the world where the high cost of exploration and characterization precludes the development of CBM resources for local use.

Introduction

The State of Alaska has been funding a geological assessment of the potential of CBM resources since 1994. Potential CBM resources have been identified in the northern portion of Cook Inlet Basin and in Alaska's frontier basins. Using a production or productivity model, on-site field investigations, and published geologic and geographic data, three coal basins were designated as representative of prospective producing CBM geologic settings in rural Alaska: western North Slope Basin near Wainwright, Yukon Flats Basin at Fort Yukon, and Alaska Peninsula near three Chignik Bay communities, (Clough, 2000). Further studies have examined the cost of drilling for CBM exploration, resource assessment, and field development in remote Alaska, and also the impact of drilling costs associated with CBM development on the energy economics of Alaskan subsistence communities (Ogbe et al., 1998; Foster, 1997). In all, at least 25 Native Alaskan communities lie directly over, or are immediately adjacent to, coal deposits that may be capable of methane production. These same communities pay State-subsidized electric utility rates for diesel-fueled power generation of roughly three to ten times the national average. Foster (1997) identifies the high cost of exploration and development associated with transportation, site preparation, rig mobilization, and associated day rates for remote operations as all contributing to marginal economic prospects for CBM exploitation at remote Alaskan locations.

For the past five years Los Alamos National Laboratory, supported by the U.S. Department of Energy, and in collaboration with major oil companies and oil field service providers, has lead the development of a subsurface exploration capability, termed "microhole drilling and instrumentation technology." Microhole technology offers a substantial reduction in exploration and development costs. Simple in concept, the microhole technology reduces drilled-hole size to the smallest size compatible with good drilling practice and continued access of instrumentation for subsurface measurements. Figure A gives micro-hole diameters relative to the diameters of conventional gas exploration and production wells. Microholes have from 1/25th to 1/50th of the cross-sectional area of these wells. Nevertheless, microhole with diameters in this range are about the same size as the typical velocity string through which gas is produced in conventional wells susceptible to logging off. By decreasing terminal-depth hole-diameter to sizes in the range of from 1-1/4 to 2/-3/8 inches, the economics of CBM exploration and development is greatly altered with overall costs approaching 30 to 40 percent of that possible with conventional exploration drilling systems. Figure B gives the overall perspective relative costs of microholes compared to conventional gas wells drilled for exploration and field development in remote Alaska. The ratios of costs are relatively independent of the absolute cost of drilling conventional wells at any given location. The potential savings that may be

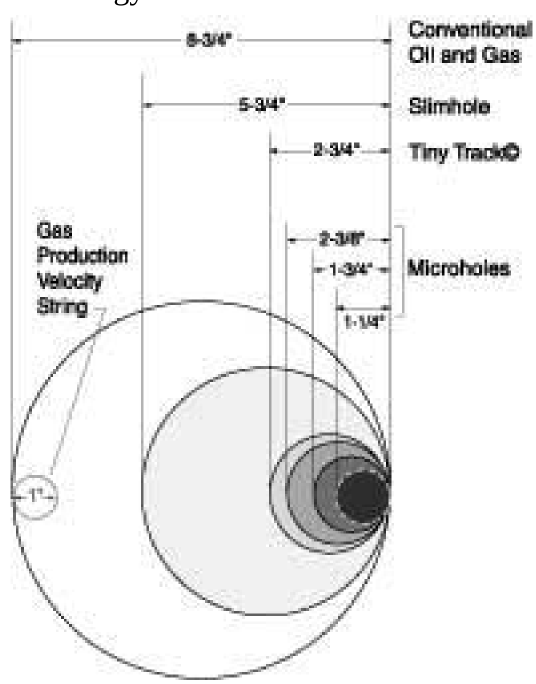


Fig. A.Relative dimensions of convention-al wells and microholes.

realized using microholes for exploration and development of CMB resources justifies serious evaluation microhole technology.

Microhole technology for CBM exploration and development

The capability to access, characterize, and develop CBM resources using microhole technology requires the integration of drilling, logging, coring, and drill-stem testing capabilities into a single system in order to realize the maximum possible cost-saving. A microhole system has yet to be designed and fabricated that meets requirements for Arctic drilling and CBM characterization. Nor does the hardware and instrumentation for hard-rock drilling, logging and testing gas-bearing coalbeds exist at this time in the small diameters required for use in microholes. Nevertheless, it is instructive to examine the status of, and the development requirements for microhole technology, if it is to be considered a candidate for use in CBM resource exploration in remote regions.

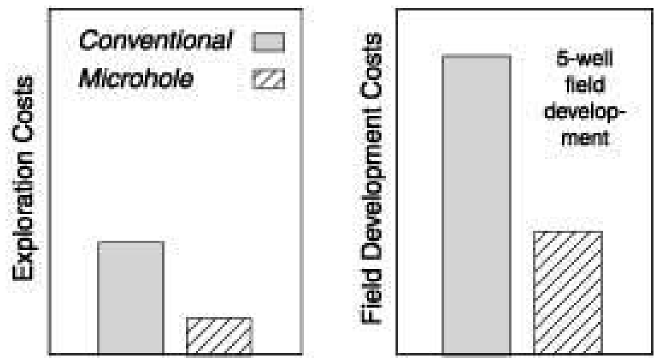


Fig. B. Relative costs of conventional wells and micro-holes used for exploration and field development.

Straight, near-vertical microholes are currently being drilled in soft and medium-hard rock using a coiled-tubing drilling system and mud-based drilling fluids. The use of a coiled-tubing drill string is compatible with a high integrity, wellhead pressure control during drilling that is essential for safe exploration drilling and formation testing. Microhole technology developments to date have focused on: systems integration and accessing the performance of the smallest drilling components that are commercially available; understanding and solving the technical obstacles of decreasing hole size on drilling depth (Dreesen and Albright, 2000); and determining limitations that basic logging tools may have as a consequence of miniaturization (Albright, 2000). Los Alamos has assembled an experimental drilling platform conducted shallow microhole drilling tests (Thomson et al., 1999), and designed, fabricated, and evaluated the performance of microhole instrumentation packages (Albright et al., 1998, 1999). While substantial development of microhole technology has occurred, the particular technical challenges facing the application of microhole technology to CBM development have not been addressed in any detail. Nevertheless, the approach to satisfying CBM exploration requirements in Alaska, can be met through developments and demonstrations that we identify as follows:

- Arctic Microhole Drilling Package (AMDP) – the development of a helicopter-portable microhole drilling system that will meet Arctic requirements for drilling, characterizing and producing the CBM resources in remote Alaska.
- AMDP-associated hardware and systems – system components and coiled-tubing drilling assemblies for efficiently penetrating glacial till and drilling 1-1/4 to 2-3/8-inch-diameter holes to 3000 ft.

- Coiled-tubing bottomhole-deployed coring – assembly to isolate a conventional core bit and barrel from the drill motor vibration.
- Arctic mud logger – gas analyzer and formation cuttings sampler operable in Arctic conditions.
- Microhole wireline logging tools – simplification, miniaturization, fabrication, and testing of conventional caliper and formation density logging tools for identifying coal beds.
- Drill-stem testing hardware – microhole zone isolation and hydrologic testing hardware.
- De-watering and production capability – assessment of the feasibility of field development using microholes.

The following sections describe the necessity for each of the above developments for CBM exploitation in Alaska, the status of the technological resources that can be brought to bear on that development.

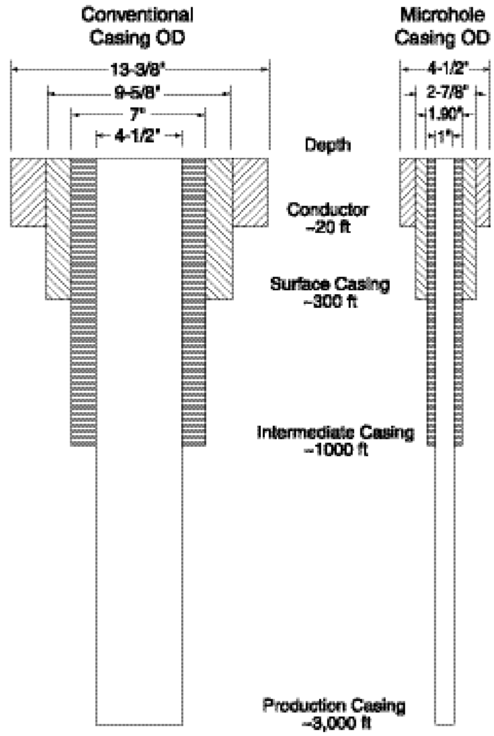
Arctic Microhole Drilling Package

Significant reduction in the scale of operations is important if exploration and development of CBM resources are to be accomplished in the Alaskan bush. With current technology, an estimated 250,000 lbs. of drilling, well completion, and logging equipment (Ogbe et al., 1998) are required for exploration of CBM resources at any given Alaskan site. Mobilization of this equipment requires shipping by barge or airfreight if development is to occur in remote Alaska.

With the substitution of microhole technology for conventional drilling, significant weight (and thereby cost) reductions are accrued due to the decrease in the size of the drill stem, the rig support structure, surface pits and tanks, and expendables (including casing, drilling fluids additives and cement). Compared to existing commercial drilling systems, the AMDP will substantially reduce the required drill-pad area. Improved automation of a coiled-tubing-deployed drilling system would result in further efficiencies.

Use of microhole equipment and materials results in approximately 75-percent reduction in shipping costs compared to those required for conventional operations. Furthermore, with proper attention to design, the largest microhole drilling subsystems can be capable of being broken down into helicopter-transportable, 4,000-lb. units. Substitution of microholes for conventional technology for CBM development at remote locations such as Wainwright, Alaska would result in an anticipated savings of $1.17M out of the $1.76M as estimated by Ogbe et al. (1998) that would be required for exploration of the site. Figure C shows one area in which savings occur. It compares completion schedules of conventional and microhole wells along with the cost and shipping weights of their respective casings. The cost and shipping weight of microhole casing are 1/7th and 1/8th, respectively, of the comparable conventional well.

The only microhole drilling system in existence is experimental and located at Los Alamos National Laboratory (Thomson, et al., 1999). With little exception, the system Los Alamos has designed consists of the integration of equipment that has been procured under development contracts, or “off-the-shelf” from commercial suppliers (Figure D). The system is currently configured for near vertical microhole drilling in shallow-soft and medium-hard formations. The Los Alamos system has been used to test and evaluate microhole components and equipment as they have become available or have been developed.. However, the Los Alamos microhole drilling system in its present state of development does not meet the requirements for CBM exploration.



Conventional			Microhole		
OD (in.)	Cost ($)	Casing Weight (lbs)	OD (in.)	Cost ($)	Casing Weight (lbs)
13-3/8	763	1,090	4-1/2	147	210
9-5/8	6,783	8,690	2-7/8	1,754	2.505
7	16,100	23,000	1.90	2,030	2,900
4-1/2	22,050	31,500	1	2,850	2,250
Total	45,696	66,280	Total	6,781	8,165

Fig. C.-Completion schedules shipping weight and cost of a microhole versus a conventional well.

Based on our current level of experience we believe that a successful microhole system will consist of the following characteristics:

- A coiled-tubing drilling unit capable of:
  - ✓ Drilling 2-3/8-inch microholes up to 2500-ft and casing with 1-2/3-inch steel casing;
  - ✓ Drilling or coring and drill-stem testing of 1-1/4-inch microholes up to 3000-ft; and
  - ✓ Being helicopter transported in modules weighing 4000 lbs or less.
- Coiled-tubing deployed, hydraulic (mud) powered drilling and coring assemblies suitable for penetrating frozen and unfrozen glacial deposits, typical sedimentary formations and coal;
- Mud pump, pits and automated cleaning system;
- Automated data acquisition and integrated control for auxiliary subsystems; and
- Total weight less than 32,000 lbs.

AMDP Associated Hardware and Systems Development

While microhole drilling technology has been demonstrated on a limited basis, the total complement of hardware and equipment necessary for microdrilling in a combination of glacial till, permafrost, hydrates, hard shallow formations, and pressurized gas reservoirs, is either not currently available through commercial sources, or has not been assembled into one drilling system. An inventory of the types of equipment that is necessary is given in Table 1.

Table 1. Inventory of hardware and equipment for a highly capable microhole drilling system.

- ✓ A 1-inch-ouside diameter (OD) rotary drilling motor with a minimum of 3-hp output fabricated for service in deep-well operations. Completion of this motor is necessary in order to use the 3/4-inch-coiled tubing necessary to meet weight specifications for the AMDP.
- ✓ A 1-inch-OD rotary-percussion bottomhole assembly for effective penetration of glacial deposits and particularly hard sedimentary formations. Conventional percussion bit technology, where rotary table movement causes the rotary movement of the bit, is well advanced. To adapt percussion drilling to the microhole coiled-tubing drilling system, rotary motion must be provided from a downhole motor or angular advance mechanism.
- ✓ A weight-on-bit bottomhole and torque sensor in the bottomhole assembly for drilling process control. This will assure real-time control of bit thrust delivered by the coiled-tubing injector, and will increase the performance of the drilling system and life of the bit.
- ✓ A mud mixing and conditioning system with a continuous, automated control and mixing system and real-time mud rheology measurement to support optimum mud conditioning. Optimum mud properties are necessary for efficient drill-cuttings transport and with maximum hydraulic power delivered to the bottomhole assembly. Major design requirements for this system will be: compatibility with operations at Arctic temperatures; a capability for controlling mud temperature needed for drilling hydrates and permafrost; and a capability for meeting special environmental provisions required for Arctic operations.
- ✓ An assortment of commercially manufactured 1-1/4- to 2-3/8-inch rotary-percussion and rotary bits. These bits will be tested and down-selected to a few bit designs suitable for deep-well microhole.
- ✓ Ancillary equipment consisting of blowout preventer flow lines, fishing tools, spears, overshots, jars, bumper subs, pulling tools.
- ✓ A mud logging and cuttings sampling system that is continuous and fully automated to measure methane and CO2 gas, and to collect cuttings samples (an unmanned mud-logging unit with automated cuttings sampling).

Bottomhole Assembly for Coring

The smallest standard commercial coring bits are the DCDMA (Diamond Core Drill Manufacturers Association) RWT bits which kerfs a hole size of 1.160 inch to cut a 0.735-inch core. This coring assembly is run on a 1.098-inch OD by 0.719-inch internal-diameter

(ID) RW drill rod. This core bit and core barrel can be run below a 1-inch OD positive displacement motor (PDM) on an RW rod and a vibration isolation sub. Core recovery will be greatly improved if bit vibrations are damped by isolating the core barrel from the motor induced vibrations in the upper drilling assembly. The sub will have to be developed to dampen the oscillation of the core barrel caused by eccentric rotation of the rotor in a PDM and to bypass excess mud flow needed to power the motor but excessive for good coring practice.

Microhole Logging Tools for CBM

Conventional oil-field logging tools, the smallest standard size of which is 1-11/16-inch diameter, are too large in diameter to be used in CBM microholes that require 7/8-inch-diameter tools. Three logging tools are routinely relied on for stratigraphic identification of coalbeds – gamma, caliper, and bulk density logs. Consequently a minimalist approach to logging CMB exploration well would include only these logs. Other diagnostic tools, including sonic, resistivity, and pulse-neutron tools, also have been used, but much less frequently.

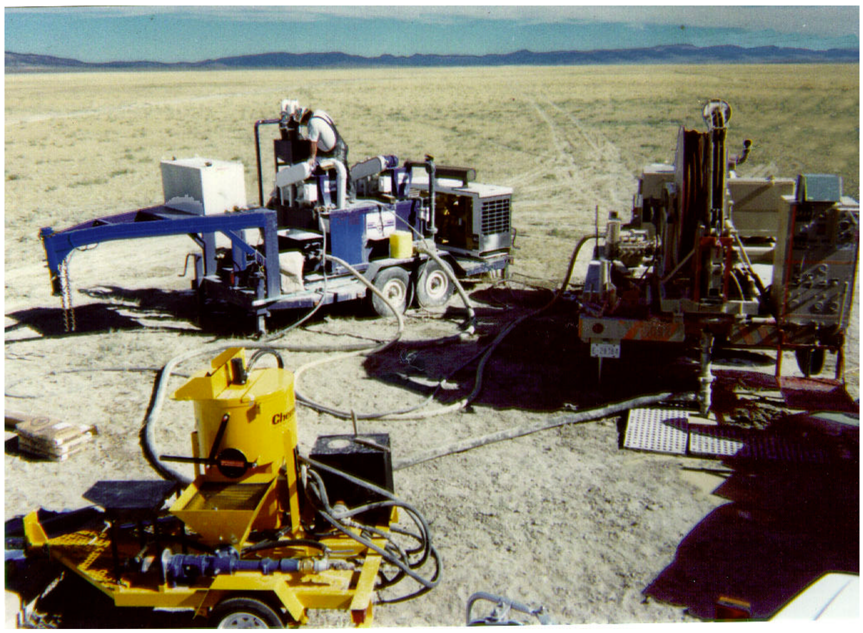


Fig. D. Microhole drill rig (right), mud system (upper left) and batch cement mixer (lower left) at field site in central Nevada. These microholes were being drilled for emplacement of seismic instrumentation packages.

Coalbeds are recognizable on gamma logs by virtue of low radioactivity, but can be confused with very clean, low-shale-content sandstones having a comparably low activity. The most indicative log measurement is the formation or bulk density log (Hollub and Schafer, 1992). Bulk density logs can lead to erroneous interpretations because, unless the caliper of the borehole is known, washouts can be mistaken for low-density formations. Hence, a caliper log is also required.

While the practice in the oil industry has been to use the formation density and neutron logs to discriminate between the water and fluid hydrocarbon saturation of most types of gas-producing formations, this has not been possible for coal. The formation density log,

however, provides the most direct measurement of the low density of coal (1.2 to 1.8 g/cc) versus other formations, and so it is relied on for stratigraphic identification.
Recent testing of a 7/8-inch-diameter gamma tool based on a conventional design, has shown that a gamma tool sufficiently small for use in microholes (Albright, 2000) can be expected to provide adequate identification in conjunction with the density and caliper logs. Measurement of the attenuation of gamma rays between a source and detector in the tool, forms the basis for the bulk density measurement; consequently, Los Alamos gamma microtool studies are directly applicable. Because relative, rather than an absolute, measurement of bulk density is required for coalbed identification, precise calibration is not viewed as a critical issue.

A multi-arm borehole caliper log will also be required for reliable drill-stem testing using packers, and is desirable for running casing and sizing cement volumes for cementing casing and spotting cement plugs. Although a caliper tool does not currently exist in microhole dimensions, a design for the miniaturization of a full-sized tool would appear to be straightforward.

In order to deploy this equipment a small highly portable wireline unit and associated data-acquisition system will be required. Coiled-tubing deployment of the logging tools may be feasible for second-generation design tools.

Drill-Stem Testing Hardware

Measurement of downhole pressure transients in response to injection or drawdown (so-called drill-stem tests or DSTs) are used to evaluate important reservoir characteristics such as permeability, wellbore damage, fluid properties, reservoir pressure (with respect to desorption), and reservoir boundaries for prediction of reservoir performance. These measurements should be made at each potential methane-producing coal zone as the hole is being drilled so that zone isolation requires less hardware. For Alaskan CBM characterization, these measurements will be made in a second microhole drilled at each site using coal depth and bed thickness derived from logs run in the first well. Depending on whether the zone is capable of flowing gas to the surface or not, the test is performed by measuring the pressure above and below a packer, either with the well flowing, under injection, or shut-in. To the best of our knowledge, DSTs have not been conducted in holes of microhole sizes using coiled tubing.

The basic standard downhole equipment for a CBM DST consists of an open-hole packer, pressure/temperature recorders (above and below the packer), a test valve located above the packer (used to control the flow path), and a sample chamber (used to catch uncontaminated reservoir fluid). In addition, jars, a slip joint, and a safety joint are often used. The pressure/temperature measurements can be made with downhole recording Kuster-type gauges, or if instrument cabling exists through the coiled tubing, downhole instrumentation with surface readout. Real time surface readout is an extremely valuable feature, allowing modifications to optimize the test procedure as data are viewed. The smallest commercially available coiled-tubing inflatable packers are 1-11/16-inches diameter (deflated) designed for use inside 2-3/8- to 2-7/8-inch tubing having a 2.47-inch internal diameter, and purported to be suitable for open-hole service. These are not, however, suitable for the 1-3/8-inch-hole size, but have basic design features that can be miniaturized for microhole applications.

Not currently known are any limitations in applying conventional analysis and interpretation of DST to microhole data for characterizing the production potential of CBM. Any such limitations must be taken into account in developing a test plan for CBM characterization at remote sites.

De-watering and Production Potential of Microholes

The use of microholes for CBM production will be contingent on the development of a suitable well completion and stimulation method. If the open hole completion and dewatering stimulate gas production without inducing wellbore instability, gas production from microholes should be feasible with little development. If more complex techniques are required to complete the well or stimulate the coal, then a significant research and development effort with high risk will be needed. Production of unstable formation or a propensity for scale, ice, or hydrate formation that plugs the well will preclude microwell production.   If microholes can be used for de-watering and production, then the need for commercial-sized equipment for the drilling of these holes can be avoided. Gas production from what is ordinarily termed “stripper production” is often accomplished using velocity tubing strings having a diameter less that that of a cased microhole. Production from velocity strings is of the order of 10 to 100 Mcf depending on reservoir pressure. A number of microholes capable of stripper-volume production would be entirely sufficient for remote community needs.   Consequently, it is well worth examining the role microholes could serve in gas production because of the potential enormous economic impact microholes could have in field development of CBM resources in remote areas.

Summary

We have examined technologic challenges and economic advantages associated with the miniaturization of conventional coiled-tubing drilling technologies to microhole dimensions. We have identified areas in which engineering development must take place in order for microhole technologies to be of benefit in CBM development. In the case of CBM development in remote Alaska, the availability of microhole technologies can potentially provide the impetus to develop CBM resources that would not otherwise be economically justified. The marginal economics of CBM production in Alaska is exacerbated by transportation costs associated with the mobilization and use of conventional drilling equipment. Yet the resource is widespread and is possibly capable of providing energy for any community located in the coal-bearing basins. The implementation of microhole technology for exploration close to remote communities with CBM development potential can make CBM an attractive economic and environmental alternative to the transportation and use of diesel upon which these remote communities must now subsist.

Publications

Albright, J.N., 2000, “Microhole technology – progress on borehole instrumentation development.” 7th International Symposium on Borehole Geophysics for Minerals Geotechnical, and Environmental Applications, Oct. 24-26, Golden CO.

Albright, J.N. and D.S. Dreesen, 2000, “Microhole technology lowers reservoir exploration characterization costs,” *Oil and Gas Journal* 98(2):39-41.

Albright, J.N., J.C. Gannon, T.D. Fairbanks, and J.T. Rutledge, 1999, “Borehole testing of a micromachined silicon accelerometer,” *Proceedings of the Annual Meeting of the Society of Exploration Geophysicists*, Houston, TX.

Albright, J.N., Woo, D.W., Fairbanks, T.D., Rutledge., Thomson, J.C., Howlett, D., and Barge, D., 1998, “Development and testing of a 0.5-inch microhole geophone package,” *Proceedings of the SEG Annual Meeting*, September 14-17, New Orleans LA.

Clough, J.G., 2000, “Assessing coalbed methane gas for rural Alaska energy needs,” Workshop on Opportunities in Alaska Coalbed Methane, Anchorage, Alaska, March 1-3.

Dreesen, D. S. and J. N. Albright, 2000. “Models support potential for drilling deep microholes,” *Oil and Gas Journal* 98(3):58-62, 2000.

Foster, M. 1997, “Rural Alaska natural gas study – A profile of natural gas energy substitution in rural Alaska,” Final Report prepared for the State of Alaska, Department of Community and Regional Affairs, Division of Energy.

Hollub, V.A. and P. S. Schafer, 1992, “A guide to coalbed methane operations,” Gas Research Institute Report.

Ogbe, D. O., J.E. Bott, and M. Hawley, 1998, “Economic analysis of drilling three coalbed methane wells in rural Alaska.” Report to the State of Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys.

Thomson, J.C., J. Hufford, and Dreesen, D.S., 1999, “Coiled-tubing Microdrilling Drilling Demonstration in Basin and Dry Lake Sediments,” Los Alamos Report (LAUR-99-5310).